STUDENTS AS SIGNAL SOURCES IN THE BIOMEDICAL ENGINEERING LABORATORY

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Abstract

Laboratory courses are used throughout Biomedical Engineering curriculum to give students hands-on, practical experience in scientific, computing and engineering methods. Interest in student-driven, inquiry-based labs has resulted in the availability of new teaching equipment for the exploration of biological systems and physiological processes. The movement to student-driven, inquiry-based labs is rooted in the belief that students will improve their critical thinking skills, achieve a greater understanding of processes explored in the lab and experience reduced frustration when gathering data. New teaching equipment allows for relatively easy collection of real-time physiological data: ECG, EEG, EMG, EOG (eye movement), pulse, skin temperature, respiration (flow and volume), limb and joint motion (distance, velocity and acceleration), electrodermal activity and response, muscle strength. New teaching equipment can aid the transition from instructor-dictated to student-driven laboratories. As students collect data directly from their own bodies, the process therein will stimulate their curiosity and give them more control over their own learning by allowing them to test and retest to more fully understand the steps involved in scientific inquiry. Student-driven laboratory settings can increase student understanding of biomedical engineering principles as well as increase student appreciation of the scientific process.

Laboratory courses are used throughout Biomedical Engineering curriculum to give students hands-on, practical experience in scientific, computing and engineering methods. Computerized data acquisition and analysis teaching systems, such as the BIOPAC Student Lab, provide a strong, multi-discipline alternative to conventional classroom approaches. Additionally, computerized teaching systems for the Biomedical Engineering laboratory can effectively augment distance learning and Internet education programs.

Interest in student-driven, inquiry-based labs has resulted in the development of new teaching equipment for the exploration of biological systems and physiological processes. The movement to student-driven, inquiry-based labs is rooted in the belief that students will improve their critical thinking skills, achieve a greater understanding of processes explored in the lab and experience reduced frustration when gathering data[1]. Through laboratory investigation, students learn to:

- Design experiments
- Interpret data
- Produce technical reports
- Measure signals relevant to biological systems
- Modify experimental procedure
- Compare measured results to theoretical values

Computerized data acquisition and analysis teaching systems allow students to collect data efficiently, evaluate it and design new experiments during the laboratory period. Students have sufficient time to evaluate the data, correct any mistakes and expand the scope of investigation. Students can easily continue the analysis outside of the lab, and can compare results with other students to expand conclusions and/or assess variance factors and repeatability issues.

Computerized lab setups not only make data collection easier, but also allow students to perform analyses that are impossible on traditional lab equipment such as a chart recorder. Students can cut and paste sections of data, perform mathematical and statistical transformations, and copy data to other applications (such as a drawing program or spreadsheet). By employing a mantle of specialized teaching software to optionally control the data collection, processing and analysis characteristics of a conventional data acquisition system, new opportunities are presented to the teacher and student for the understanding of often very complex and interdisciplinary biomedical engineering principles.

Students learn that very sophisticated equipment can be easy to use. Because historically difficult physiological recordings are greatly simplified by using the BIOPAC Student Lab, students are provided more freedom to make mistakes and learn from them

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in a non-intimidating manner. For example, collection of the following types of physiological data can take place very quickly, providing sufficient time for the student to analyze data and repeat experiments, if necessary.

- ECG
- EEG
- EMG
- EOG (eye movement)
- Pulse
- Skin temperature
- Respiration (flow and volume)
- Limb/Joint motion (distance and velocity)
- Electrodermal activity and response
- Muscle strength

Computerized data acquisition systems designed for the Biomedical Engineering teaching laboratory, like the BIOPAC Student Lab, provide significant advantages over conventional and general-purpose instrumentation. The characteristics of such equipment provide for:

1) Automatic detection of transducer types placed at system inputs

2) Automatic assignment of proper scaling and units to different physical signals

3) Textual guides to help students through the following key processes in a programmed lesson structure:

   A) Signal Calibration
   B) Data Collection
   C) Data Processing
   D) Analysis of Processed Data
   E) Data Porting for Specialized Analysis
   F) Experiment Modification

4) System software operational modes which permit specialized experiment design:

   A) Instructors can easily design new experiments for all students by customizing menu displays, adding journal text such as an existing lesson plan, and creating lesson template files for specific protocols
   B) Students can perform independent experiment design
   C) System can be programmed to collect data from conventional lab sources

5) General-purpose data porting which permits experimental data transfer to other applications:

   A) Students can submit lab reports in conventional word processor format
   B) Students can exchange data remotely with teacher and other students
   C) Students can access websites for shared data or experiment setups

6) Computerized data formats permit location flexibility for:

   A) Distance Learning — system is portable and cross-platform compatible
   B) Internet Education — system can be connected to a network

It is important that students learn to evaluate their experimental procedures and see the impact on their results. When students encounter less difficulty during the processes of equipment setup, calibration and data collection, they are afforded more time in the lab to analyze and understand data and the complicated principles associated with collecting it.

For example, in the Pulmonary Function lab (a component lab of the BIOPAC Student Lab), conventional setup and calibration might take literally hours, but with the automated setup and calibration provided by computerized teaching systems, students can be recording within minutes, leaving considerable time to focus on scientific inquiry and principles.

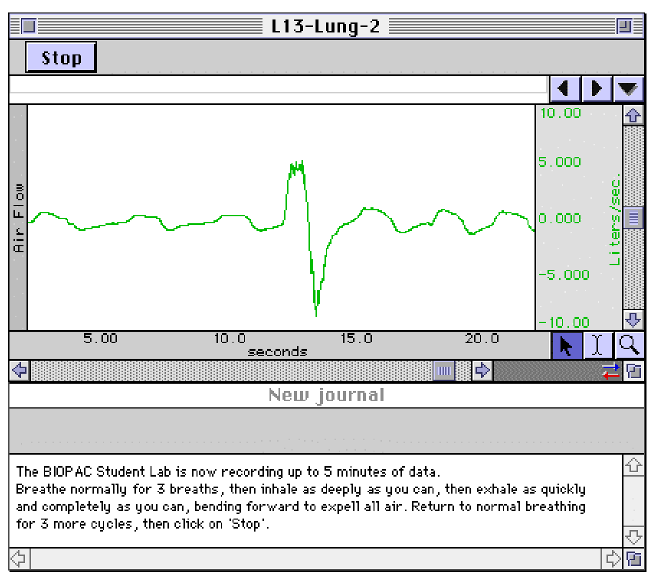

Figure 1: Air Flow Data Collected in the Pulmonary Function Lab

From a biomedical engineering perspective, computerized teaching systems can quickly cover a wide range of disciplines. For example, in the Pulmonary Function lab, a pneumotach is used to obtain ventilation data. The simple design of the pneumotach permits an easy engineering evaluation.

The pneumotach consists of a hollow passage that passes the air inspired and expired by the student. The passage contains an internal wire mesh screen that creates a pressure differential from one side of the screen to the other as air flows through the screen. A differential pressure transducer senses this pressure difference. The differential pressure transducer is of classic (four element) bridge design and is driven by an excitation voltage. The bridge returns a differential voltage proportional to the differential pressure sensed. The differential voltage is amplified by a differential amplifier, lowpass filtered and then digitized through the use of an A/D converter. The converter samples the signal at sufficient speed to satisfy the Nyquist criteria. The airflow data is then presented to the student in a graphical form on the computer screen.

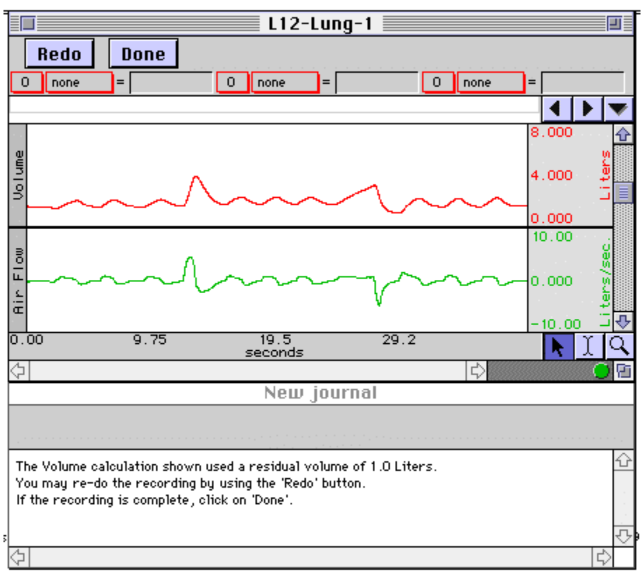

Figure 2: Volume Calculation from the Pulmonary Function Lab

Once the flow data is present, the student sees the data integration process take place and so experiences the presentation of volumetric data. The volumetric data obtained from the student's lungs can then be compared to standard physiological references.

The Pulmonary Function lab structure permits the instructor to emphasize the principles relevant for the curriculum.

For example, considerable attention could be given to the meaning of transducer calibration.

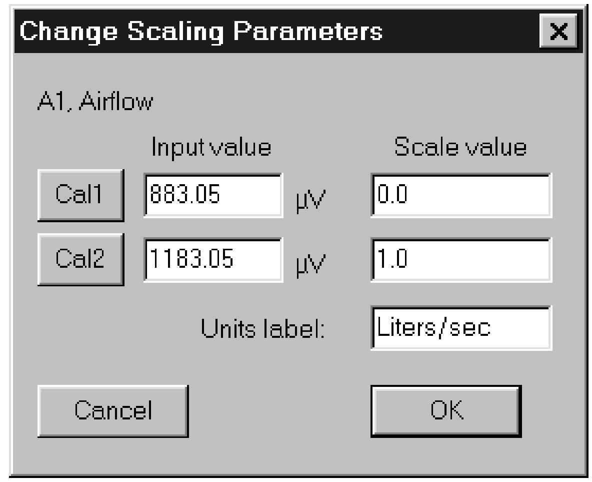

Figure 3: Calibration Parameters from Computerized Lab Software

In this lab, the calibration signal source is a fixed volume gas syringe. The student connects the syringe to the pneumotach and forces a defined gas volume through the pneumotach. The pneumotach records the gas flow. The flow must be integrated to obtain a volume. The student evaluates the resultant volume and compares it to the known volume of the syringe. Alternatively, emphasis can be applied to physiological-based variables. Lung volume and forced expiratory flow data can be compared to known standard mean values. In addition, comparisons can be performed respective to other students, thus incorporating possible gender, height and weight variances.

For advanced teaching applications, the software presentation format can be changed to provide the student additional degrees of freedom. Accordingly, as students become more sophisticated, layers of the guiding software can be removed to allow the students increased flexibility in problem solving when presented with data collection and analysis scenarios. In this mode, advanced students can work on completely unique experiments, in a set lab period, without compromising their understanding of basic principles.

For example, hardware settings such as amplifier gain and anti-aliasing filtering can be modified as required. Advanced digital filters, consisting of a series of sequential second-order biquads, can be configured to obtain optimal signal-to-noise or desired wave-shaping in the recording. Filters can be constructed to

achieve constant group delay or specific passband flatness. Notch filters (for 50/60 Hz filtering) can be added to experimental protocols.

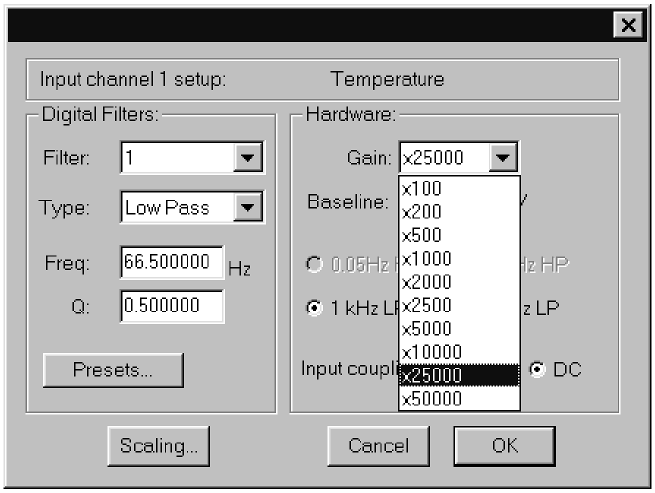

Figure 4: Gain and Filtering Settings

Numerous real-time transformations permit students to operate on data as it's being collected. Data can be filtered, rectified, differentiated, and integrated in real-time or post processing. Time series analysis features, such as signal rate detection, permit the student to easily quantify complex physiological signals. A comprehensive set of post-processing functions exists for the student to analyze data after the recording session.

Specialized teaching software associated with data acquisition systems permits the student to encounter the laboratory hurdles of proper amplification, signal calibration, scaling and unit assignment, signal processing and analysis, without encountering the myriad setup challenges and time loss conventional equipment presents.

The BIOPAC Student Lab can aid in the transition process from instructor-dictated to student-driven, inquiry-based laboratories. When students collect data directly from their own bodies, their curiosity is stimulated and they gain control over their own learning with the ability to test and retest to more fully understand the steps involved in scientific inquiry. Student-driven laboratory settings increase student understanding of Biomedical Engineering principles and increase student appreciation of the scientific process.

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